Astrophysics Research And Analysis

Laboratory Exploration of Exoplanet Hazes in Preparation for JWST

Completed Technology Project (2017 - 2019)

Project Introduction

Science Goals and Objectives Although it has long been postulated that clouds and hazes were important components of exoplanet atmospheres, it is only recently that observations have substantiated their existence. Clouds and/or hazes have been detected at high significance in the atmospheres of the super-Earth GJ1214b (Teq~600 K), Neptune-mass GJ436b (Teq~800 K), and hot-Jupiter Kepler-7b (Teq~1700 K). In the case of Kepler-7b in the high temperature regime, equilibrium silicate clouds provide an adequate match to the observe variations in the planetary albedo as a function of orbital phase. The nature of the clouds/hazes in the atmospheres of GJ1214b and GJ436b are more uncertain, as thick equilibrium cloud species are not expected to form this temperature regime. Thus far there are no observational indications that photochemistry (either haze formation or disequilbrium chemistry) strongly affects planets hotter than 1200 K. It is expected that photochemistry will play a much greater role in the atmospheres of planets with average temperatures below 1000 K, especially those planets that may have enhanced atmospheric metallicity and/or C/O ratios such as super-Earths and Neptune-mass planets. The Kepler mission has shown that the most populous type of planets are those for which we have no solar system analogs, super-earths (1.25 Rearth < Rp <2.0 Rearth) and mini-Neptunes (2.0 Rearth < Rp < 4.0 Rearth). The TESS mission will substantially increase the number of super-Earths and mini-Neptunes on which atmospheric characterization studies can be conducted. However, these studies will require improved experimental constraints on photochemical processes in these cooler metal-rich planetary atmospheres. Although models of atmospheric photochemistry and haze optical properties provide good first estimates, they are incomplete and biased by available solar system data. There are no solar system analogues in both size (mass and radius) and equilibrium temperature that could serve as an initial guide to haze formation in this important new sample of exoplanet atmospheres. We propose to determine the optical and solid state properties of experimentally produced exoplanet haze analogs in regimes relevant to the astrophysics missions TESS, JWST, and WFIRST. We will address the following ques- tions: What are the densities of haze particles in exoplanet atmospheres and what are their optical properties over a broad, observable wavelength region? Methodology Here we propose to investigate photochemical processes cooler metal-rich exoplanetary atmospheres in a state-of-art laboratory facility specifically designed to investigate a range of planetary atmospheres. Our laboratory experiments will produce photochemical hazes whose optical properties will be studied from the UV through the IR. Additionally, we will measure particle density to provide constraints for haze microphysics models. We will investigate the effect of gas composition, temperature, and energy source on the physical/chemical properties of haze. Relevance The proposed investigations are directly relevant to the objectives of the Astrophysics Research and Analysis Program. The experimental exploration of this atmospheric phase space will enable interpretation of current and future observations and improve our understanding of the physics and chemistry

Laboratory Exploration of Exoplanet Hazes in Preparation for JWST

Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

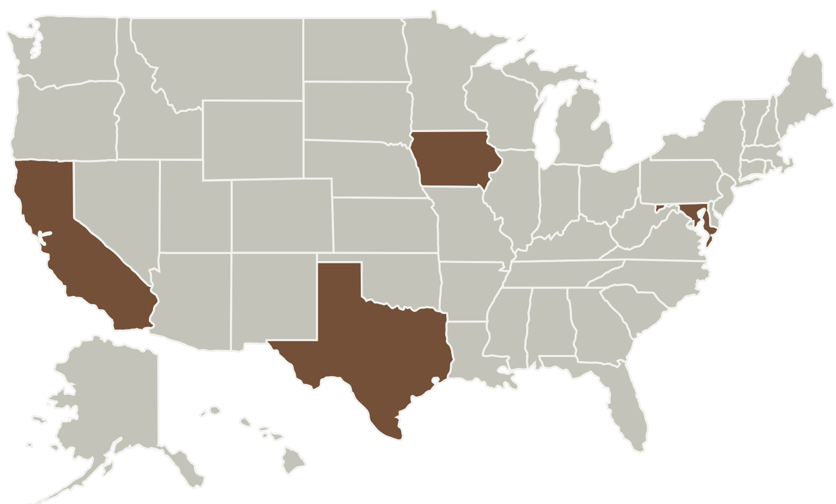
Science Mission Directorate (SMD)

Responsible Program:

Astrophysics Research and Analysis

occurring in planetary atmospheres. Specifically the proposed measurements will determine "solid-state parameters that are essential for analyzing and interpreting the data from NASA Astrophysics missions" by exploring "the spectroscopic properties of...particulate matter, as well as their chemical, physical, and dynamical properties under astrophysical conditions." The proposed investigations were specifically designed to enable analysis and interpretation of observations from JWST.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Johns Hopkins University	Supporting Organization	Academia	Baltimore, Maryland

Primary U.S. Work Locations	
California	Iowa
Maryland	Texas

Project Management

Program Director:

Michael A Garcia

Program Manager:

Dominic J Benford

Principal Investigator:

Sarah M Horst

Co-Investigators:

Nancy Kerner
Caroline V Morley
Julianne I Moses
Nikole K Lewis
Eliza Kempton

Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  - └ TX09.4 Vehicle Systems
    - └ TX09.4.5 Modeling and Simulation for EDL

Target Destination

Outside the Solar System